Togai InfraLogic, Inc.

Product Summary and Suggestions

Product Overview

Togai InfraLogic, Inc.'s (TIL) product line includes development systems for both the individual curious about fuzzy logic and the project manager looking to incorporate a fuzzy logic-based solution into end product applications. Based on the fuzzy logic activities a user is planning - from prototyping software to custom hardware - a Togai InfraLogic solution is available.

The following diagram depicts the seamless integration of the TIL product line. By mixing and matching various software tools and hardware, a user can be up and running in a fuzzy environment in a relatively short period of time.

Product Description

The following definitions provide a brief description of the various components making up the TIL product line.

TILShell - An object based, graphical window, software development environment for fuzzy expert systems. Interfaces directly with the Fuzzy-C, microFPL, and FC110 Development Systems.

Fuzzy-C Development System (FCDS) - Software tool used to generate C source code for the implementation of a fuzzy system defined in the TILShell. The Personal-FCDS is a related product serving as an exploratory or training version of the FCDS.

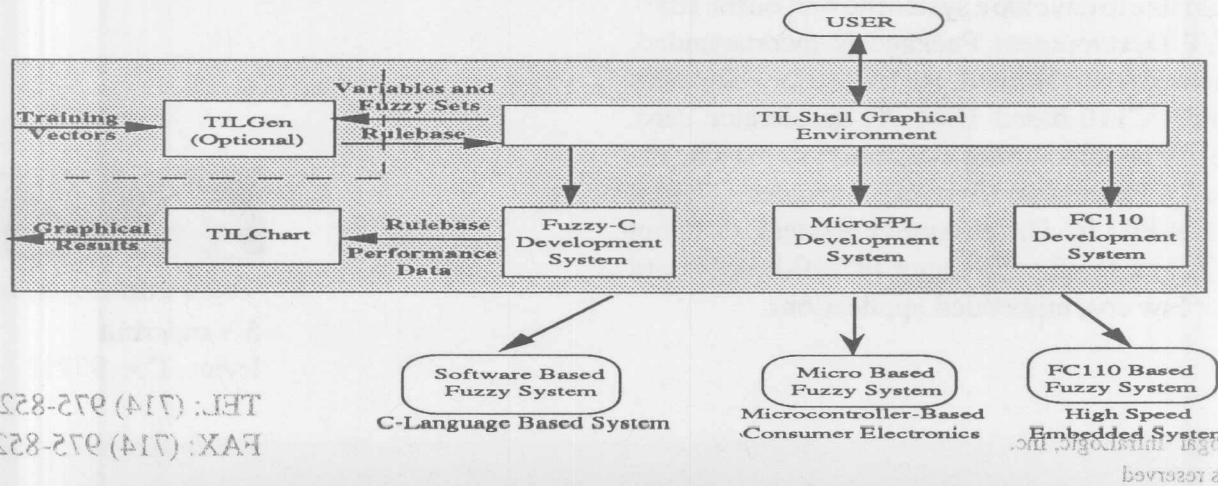
FC110 Development System - Software tool to generate fuzzy logic systems for FC110 (see below for FC110) based products. Includes compiler, assembler and linker.

MicroFPL Development System - A micro fuzzy processing kernel and compiler which generates compact fuzzy expert systems, with linkable runtime interpreter kernel for the specific target microprocessor. Available for many 8 and 16-bit microprocessors.

TILGen - An automated rulebase generation tool. Using the definitions of the inputs and outputs of a system and an input data file, TILGen will generate a fuzzy rulebase. Uses the latest in neural network techniques to analyze user's inputs and generate the output rulebase.

TILChart - A graphical analysis tool to examine performance and analyze internal data of a fuzzy logic system.

FC110 and FC110 Based Subsystems - The FC110 is a VLSI digital fuzzy logic processor that accelerates fuzzy logic computations as well as serving as a host microprocessor. VME, PC and other bus boards are available.



Togai InfraLogic's Integrated and Modular Product Family

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Product Suggestions*

If you are just curious about fuzzy logic...
If you plan on developing a simple fuzzy logic prototype system or just want to experiment with fuzzy logic, the Personal Fuzzy-C Development System is recommended. It is an inexpensive and cost-effective way of gaining working knowledge of fuzzy logic. Additionally, it has enough capability to develop a simple fuzzy system.

RECOMMENDATION: Personal-FCDS

If you are planning fuzzy logic development in C language...
The TILShell/FCDS combination will give you the power to develop sophisticated fuzzy logic systems for any target processor with a C compiler. This package also includes TILChart.

RECOMMENDATION: TILShell/FCDS Package

If you are planning fuzzy logic development for a microprocessor...
The first step is to prototype and debug the application system in a high level language. The MicroFPL Development System is then used to generate assembly code for final system integration and ROM or EPROM programming.

RECOMMENDATION: Microcontroller Development Package

If you are planning fuzzy logic development and will need very high performance...
If you would like to develop a system hosted on the IBM-PC, the AT Development Package is recommended. This kit includes the TILShell, the FC110 Development System and FC110-based IBM-PC accelerator card. Otherwise, for breadboarding a custom system using the FC110, the SA Evaluation Kit is recommended. This kit includes the FC110 Development System (without TILShell), and a small form-factor FC110-based board suitable for low cost embedded applications.

RECOMMENDATION: AT Development Package or SA Evaluation Kit

If you require automatic fuzzy rulebase generation...
In the case of extremely complex or human controlled systems, fuzzy logic control rules are often difficult to obtain. TILGen utilizes a neural network technology to automatically generate these rules by monitoring the system (in the form of training vectors). By training this data, fuzzy logic control rules can be generated that duplicate the performance of the system.

RECOMMENDATION: TILShell/FCDS/TILGen Package

If your fuzzy logic application will need to interface with analog systems...
The Single Board Fuzzy Controller (SBFC) combined with the FC110 Development System for programming capabilities is recommended.

RECOMMENDATION: Fuzzy Controller Package

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TIL Prods. 10/91

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SBus Accelerator Board

Major Features

- Two 20MHz., FC110 processors per board
- 128K bytes of knowledge base RAM per processor
- SBus slave compliant per SBus specification B.0
- SBus form factor compatible with all SBus products
- High level programming support
- 440,000 fuzzy rule evaluations per second
- Access to 64 bytes of each FC110 shared RAM
- Host access to all of the knowledge base
- Software enable/disable of four different interrupt sources
- Software control of FC110 reset

Overview

The Togai InfraLogic SBus board is a high performance single board fuzzy logic accelerator designed for complex real-time fuzzy logic applications on SBus based machines. Based on Togai InfraLogic's custom VLSI processor, the FC110 DFP™ (Digital Fuzzy Processor), this board brings a full range of fuzzy control system capability to SBus-based equipment.

The SBus accelerator board is designed around two fully supported FC110 Digital Fuzzy Processors. The FC110 is a RISC processor that contains a specialized fuzzy instruction set. This specialized instruction set allows the FC110 processor to evaluate complex fuzzy problems more quickly than conventional processors.

Applications

- Factory Automation
- Motor Control
- Robot arm control
- Real-time process control
- Sensor fusion
- Pattern recognition and classification
- High level task scheduling

Parallel Solutions

The on-board multi-processor capability can be applied to complex systems requiring processing of multiple independent knowledge bases or for processing the knowledge base in parallel. Parallel processing is available on-board via or through two FC110 processors.

Parallel processing gives control system designers flexibility to provide speed and performance for multiple, integrated control problems. Additionally, independent knowledge bases can be processed and serviced asynchronously.

System Requirements

- Sun Sparc product families based on SBus
- All SBus products
- Unix operating system

Software Tools

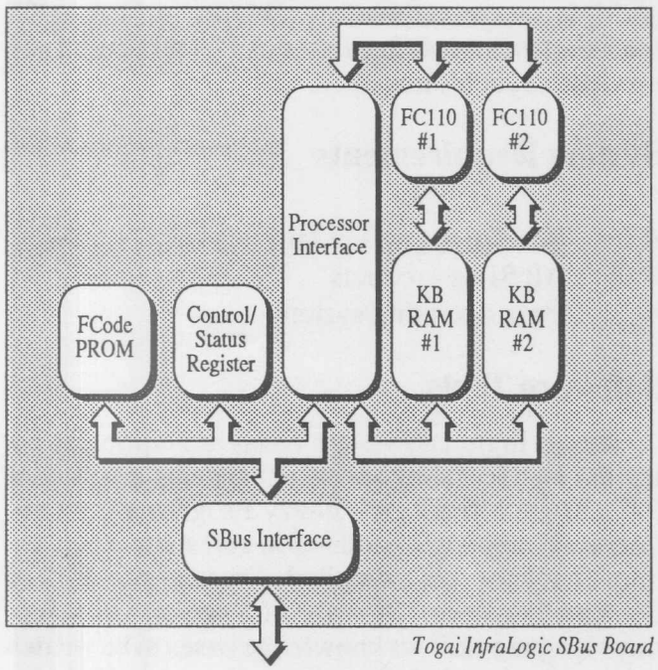
Fuzzy logic knowledge bases are compiled using the FC110 Compiler which accepts a subset of FPL, Togai InfraLogic's Fuzzy Programming Language. Fuzzy logic production rules and membership functions are compiled directly into FC110 machine language. The use of a uniform development language allows knowledge bases to be written once and compiled to various target implementations from workstations to PCs, to microcontrollers and to embedded FC110 systems without additional development.

In addition, Togai InfraLogic's TILShell™ window based software development environment interfaces directly with the FC110 compiler. Combining the SBus Accelerator Board, FC110 Compiler and the TILShell interface, provides the customer with the ability to turn an SBus, Unix-based computing platform into a fuzzy control system engineering workstation.

Board Details

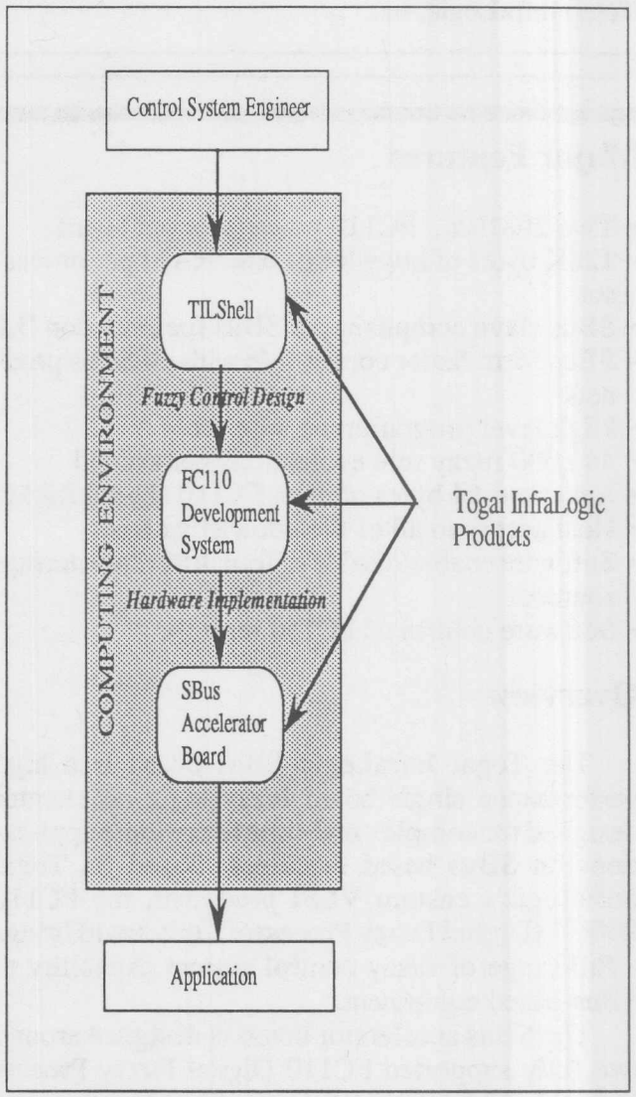
Togai InfraLogic's SBus accelerator board uses the latest in SMT and programmable array logic technology. The six layer double-sided board is manufactured using a dry etch process. All bus driver interface logic uses series output resistors to reduce overall system noise and suppress ground bounce effects.

BLOCK DIAGRAM OF SBUS BOARD AND FC110



Togai InfraLogic SBus Board

SBus Acelerator Board and TIL Product Integration



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FC110 Digital Fuzzy Processor DFP™

Major Features

- Efficient evaluation of fuzzy knowledge bases
- High level programming support
- 200,000 fuzzy rule evaluations per second
- 60,000 fully evaluated Crisp outputs per second
- Directly supports more than 800 rules
- Up to 256 IF and THEN arguments
- True microprocessor architecture and instruction set
- Interfaces directly to standard microprocessors (6800 or 8051 types)
- 256 bytes on-Chip RAM shared with Host
- 256 bytes on-chip local data RAM
- 256 bytes external Memory Mapped I/O
- 128K byte knowledge base address space
- Low power CMOS technology
- Full Harvard Architecture
- No restriction on membership function shapes, sizes or values
- 8-bit inputs/outputs/α's

General Description

The FC110 Digital Fuzzy Processor (DFP™) is a single chip VLSI processor designed for embedded fuzzy logic applications. A basic system block diagram, making use of an embedded FC110 device is shown in Figure 1.

Although simplified, the diagram shows all of the basic elements of a fuzzy logic control system built around the FC110 DFP™. The FC110 uses an architecture that allows the fuzzy knowledge base program and all of the constant data to reside in an off-chip knowledge base memory. Variable data resides in an on-chip shared data RAM that both the device and the host system can access.

The FC110 architecture is optimized for fuzzy logic knowledge base evaluation. These optimizations provide tremendous flexibility and speed improvements over existing technologies, while remaining in a form-factor desirable for embedded applications. Its interfacing capabilities allow the user to explore the full spectrum of possible system architectures, from operation as a stand alone processor to use as a co-processor. Figure 2 shows the architecture of the FC110 as a standalone device.

The FC110 supports knowledge bases with up to 128K bytes of rule and membership function information. The fuzzy rule format allows a variable number of IF and THEN statements. Rules maintain 8-bits of precision for inputs, outputs and internal truth values. The membership functions are also flexible, having up to 256 elements in the membership functions and 8-bits of membership resolution.

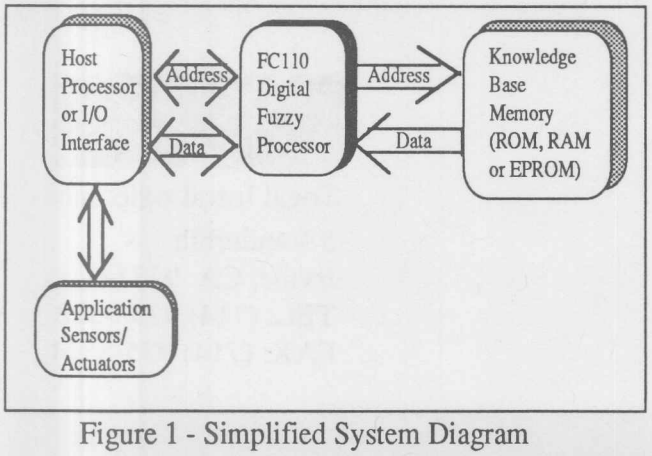

Figure 1 - Simplified System Diagram

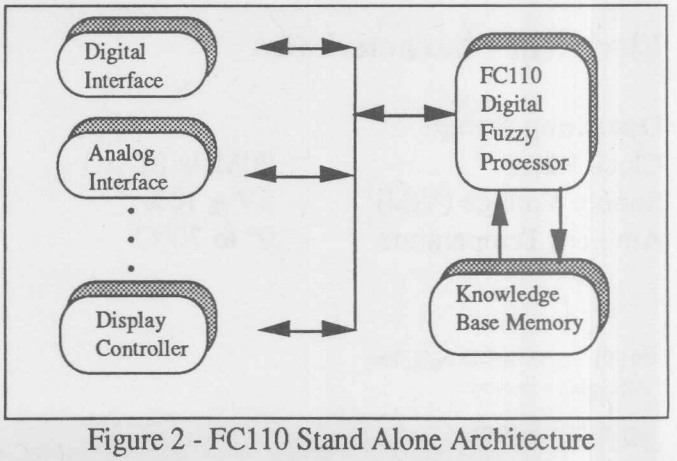

Figure 2 - FC110 Stand Alone Architecture

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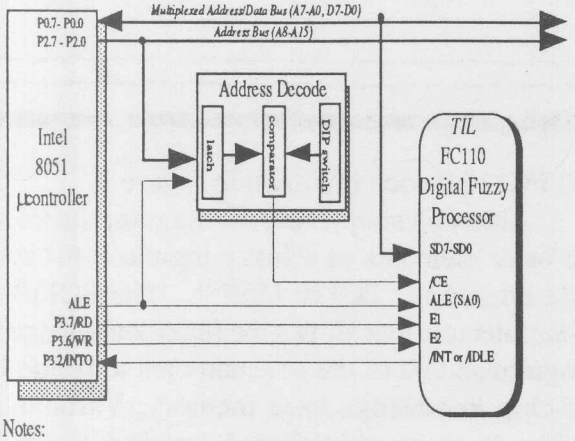
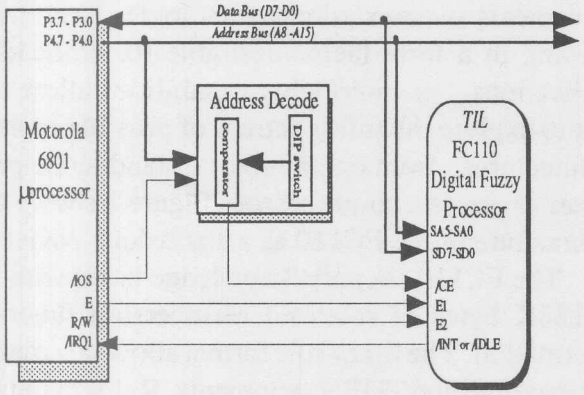
A SAMPLE FC110/8051 CONNECTION DIAGRAM



Notes:

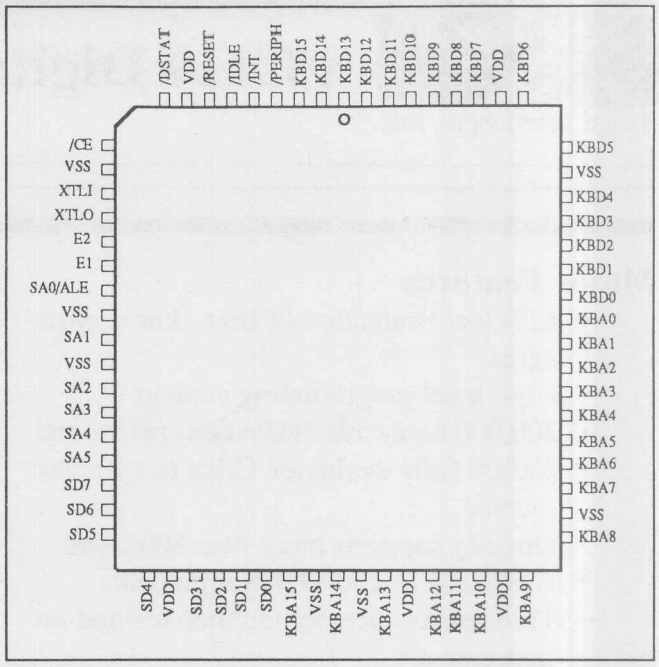
1) The 8051 can only gain access to the FC110 when the FC110 is idle.
2) The FC110 is in 8051, multiplexed mode.

A SAMPLE FC110/6801 CONNECTION DIAGRAM



Notes:

1) The 6801 can only gain access to the FC110 when the FC110 is idle.
2) The FC110 is in 6800, non-multiplexed mode.
3) The 6801 is in expanded non-multiplexed mode.



Pin Diagram

DC Characteristics

Input High Voltage (V_{IH})	2.0V (min.)
Input Low Voltage (V_{IL})	0.8V (max.)
Output High Voltage (V_{OH})	2.4V (min.)
Output Low Voltage (V_{OL})	0.4V (max.)

Capacitance

Input Capacitance	4.0pF
Output Capacitance	7.0pF
Tristate Capacitance	9.0pF

Package Type

68 pin PLCC (Plastic Leaded Chip-Carrier)

Electrical Characteristics

Operating Range

Clock Rate:	20MHz (max.)
Supply Voltage (Vdd)	5V ± 10%
Ambient Temperature	0° to 70°C

FC110 DFP™ 10/91

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Classifier/Sorter (C/S Chip)

Major Features

- Dictionary ROM interleaving for up to 8x throughput
- Choice of dictionary tag value or "closeness value" output
- Three different classification algorithms
- Definable data sample size (feature vector length)
- 16-bit 2's complement input data (feature vector element size)
- Variable sort length (100 or 52 top candidates)
- Choice of ascending or descending sort (closest or furthest)
- 4 MByte maximum dictionary size (eight way interleaved)
- Dictionary ROM power-down signal generation
- Capable of performing distance classification

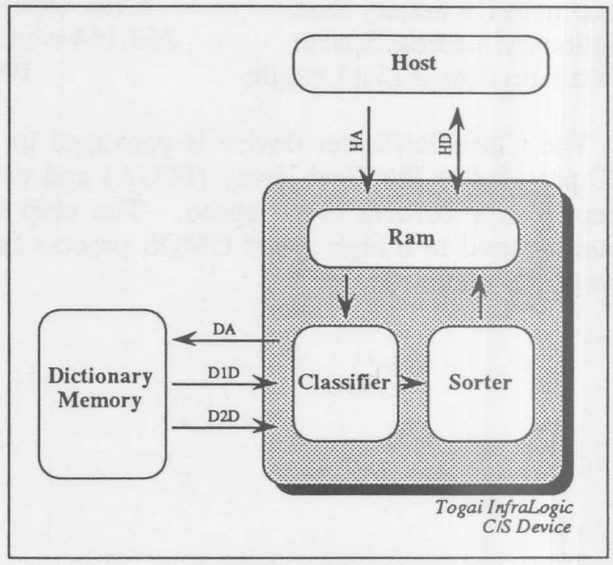
Overview

The Classifier/Sorter (C/S) device is designed to accelerate the tasks required for high-speed pattern recognition applications such as optical character recognition, target identification and machine vision. Specifically, this device compares a given vector with a list of vectors in a dictionary using one of three classification algorithms. Using the "difference" between vectors as a metric, the device creates and maintains a sorted list of the "n" closest matches. Upon completion of the dictionary evaluation, either the tag addresses of the dictionary vectors or the value of the difference between the vectors is presented to the host for further classification.

Modes of Operation

The Classifier/Sorter device operates in three basic functional modes. The device can perform a full classification and sorting task on sample data, or if the user wishes, perform a simple sort-only or classification-only routine.

The C/S also offers six possible dictionary memory interleaving configurations. These allow the designer to make direct trade-offs between the overall system speed, cost and area. A minimal system can be designed using a single dictionary ROM for a small and cost effective solution. Or, if the classification task requires maximum speed, a dictionary consisting of eight interleaved ROMs can be used. The TIL Classifier/Sorter device offers dictionary memory interleaving for one, two, three, four, six and eight ROMs.



SYSTEM BLOCK DIAGRAM

Classification Algorithms

Three different algorithms can be used when classifying a given sample against a set of dictionary entries. These algorithms are the following:

Dot Product

$$\sum x_k * w_k$$

Mean Absolute Distance

$$\sum | x_k - w_k |$$

Mean Square Distance

$$\sum (x_k - w_k)^2$$

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Summary of Performance

Example Classification/Sorting task

Dictionary length:	1,000 objects
Feature vector length per object:	32 words
Sort length:	52 candidates
Clock Frequency:	20 MHz
Rom interleaving mode:	8x
Classification/Sorting speed:	5,000 objects/sec

General

Data Word Size:	16 bits
Maximum Vector Capabilities:	201 words
Maximum Dictionary Size:	8,191 entries
Dictionary Address Space:	262,164 words
Maximum Sorted List Length:	100

The Classifier/Sorter device is packaged in a 120-pin Plastic Pin Grid Array (PPGA) and can operate at a 20MHz clock speed. The chip is manufactured in a high speed CMOS process for low power operation.

Device Pinout

120-pin Plastic Pin Grid Array (view from pin side)

	1	2	3	4	5	6	7	8	9	10	11	12	13	
N	D1D [13]	DA [0]	DA [2]	DA [4]	DA [6]	DA [7]	DA [8]	DA [9]	DA [11]	DA [13]	DA [15]	DA [16]	D2D [15]	N
M	D1D [11]	D1D [15]	DA [1]	DA [3]	DA [5]	VDD	VSS	DA [10]	DA [12]	DA [14]	DA [17]	D2D [13]	D2D [12]	M
L	D1D [10]	D1D [12]	D1D [14]	VSS	VSS	VDD	VSS	VSS	VSS	VDD	D2D [14]	D2D [11]	D2D [10]	L
K	D1D [7]	D1D [9]	VDD								VDD	D2D [9]	D2D [7]	K
J	D1D [5]	D1D [6]	D1D [8]								D2D [8]	D2D [6]	D2D [5]	J
H	D1D [2]	D1D [3]	D1D [4]								VDD	VDD	D2D [4]	H
G	D1D [1]	VDD	VDD								VSS	VSS	D2D [3]	G
F	D1D [0]	VSS	VSS								D2D [0]	D2D [1]	D2D [2]	F
E	$\overline{I4OE}$	$\overline{I3OE}$	VDD								VSS	XTLI	XTLO	E
D	$\overline{I2OE}$	$\overline{I1OE}$	VSS								VDD	ILE	$\overline{RES}$	D
C	HA [7]	HA [6]	HA [3]	VDD	VSS	HD [10]	VSS	VDD	VSS	VDD	R/W	$\overline{NPO}$	$\overline{DAE}$	C
B	HA [5]	HA [4]	HA [1]	HD [14]	HD [12]	HD [9]	VSS	VDD	HD [4]	HD [2]	HD [0]	$\overline{SEL2}$	$\overline{BUSY}$	B
A	HA [2]	HA [0]	HD [15]	HD [13]	HD [11]	HD [8]	HD [7]	HD [6]	HD [5]	HD [3]	HD [1]	$\overline{SEL1}$	$\overline{STRB}$	A

PACKAGE INDEX (inactive)

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Togai InfraLogic, Inc.

TILGen Development Tool

Major Features

- Automatically generates a fuzzy expert system rulebase from a given set of system inputs and required outputs
- Simplifies the process of creating fuzzy logic expert systems
- Functions as a neural fuzzy system extractor
- Supports three learning methods:

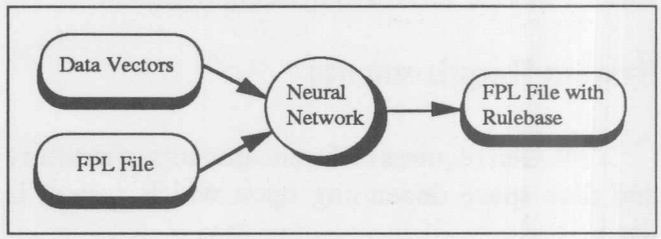
  - Unsupervised competitive learning
  - Supervised competitive learning
  - Differential competitive learning

- Works in concert with other TIL software tools such as the TILShell and Fuzzy-C Development System
- Works in conjunction with TIL Fuzzy Programming Language (FPL), specifically designed for the implementation of fuzzy logic knowledge bases

Overview

TILGen is a neural fuzzy system extractor which uses the latest in neural network learning techniques to analyze inputs and generate output. Currently, TILGen supports competitive learning, supervised competitive learning, and differential competitive learning techniques.

TILGen is a combination of two processes: a neural network that learns the input-output function described by the set of inputs and outputs, and an algorithm that decodes the neural network to generate the rules for the fuzzy expert system. As the figure below shows, TILGen takes as input an FPL file and a vector file containing the set of inputs and outputs, processes the inputs using a neural network, and produces an FPL file containing a fuzzy rulebase.



The TILGen Development Process

Learning Methods

Neural networks are trained to give a certain output based on a certain input through the use of learning methods. Generally a node of a neural network contains an activation level which during training, is increased or decreased based on how "close" the node is to the current training input. Training methods are used to change the value of the node based on this "closeness". TILGen uses one of three learning methods to train the neural network nodes:

- Unsupervised competitive learning (UCL)
- Supervised competitive learning (SCL)
- Differential Competitive Learning (DCL)

The methods work by first initializing the n nodes of the neural network with the first n test vectors. Then, each remaining vector is compared with the n nodes and the node (or nodes) which most closely match the input vector is found. These nodes are commonly referred to as the winning nodes. The nodes are then updated according to the various learning methods:

- UCL- Reward winning nodes by increasing their activation levels
- SCL- Reward winning nodes by increasing their activation levels, and punish losing nodes by decreasing their activation levels

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- DCL- Reward the "closest" winning node, and punish the other winning nodes

The results of the learning methods tend to vary. UCL and DCL however, tend to produce similar results. DCL is guaranteed to converge quickly, while UCL is not guaranteed to converge. With SCL networks more time is needed for training, along with additional information being required.

System Requirements

TILGen requires different amounts of memory and disk space depending upon which system is used.

IBM and NEC PC	1 MB hard disk space 512 KB RAM Floppy diskette drive for installation

For the graphical version of TILGen Microsoft Windows Version 3.0 is needed.

Unix Workstation	1 MB hard disk space QIC cartridge tape drive for installation
Macintosh	Macintosh Plus or better System 6.0.3 or later 1 MB hard disk space 1 MB RAM High density floppy disk for installation

TILGen is Multifinder and color compatible.

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Invented in the U.S., commercialized in Japan—an old story, but in the case of the technology known as fuzzy logic, the story may have a different ending.

Why fuzzy logic is good business

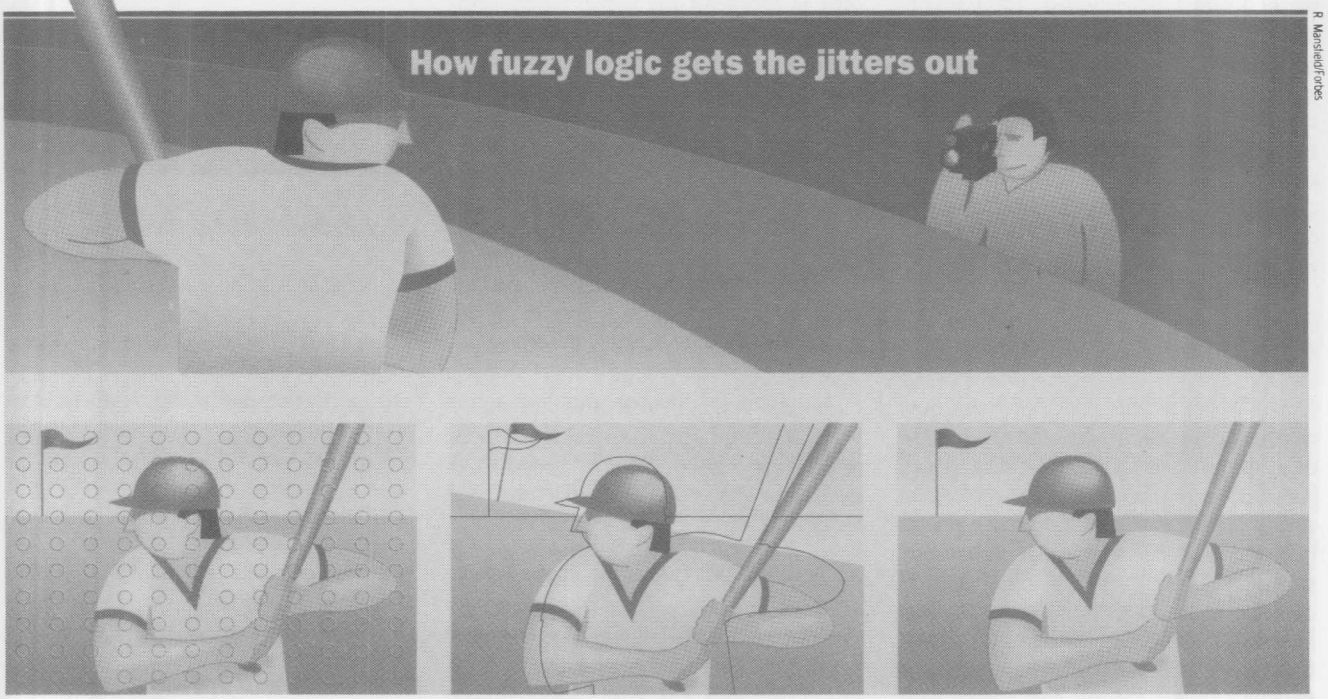
THIS IS YET another story of an important new technology that was invented in the U.S. and is being commercialized rapidly in Japan. But this one may have a happier ending so far as the U.S. is concerned.

The technology is an esoteric mathematical theory called fuzzy logic, and it is turning out to be a useful way to run all kinds of consumer products and control complex industrial processes. Virtually every Japanese home appliance maker has put fuzzy logic controllers in new models of video camcorders, vacuum cleaners, air conditioners, rice cookers, microwave ovens, toasters and refrigerators.

How is so far-out a system applied to such mundane products? The author of a fuzzy system crafts a series of rules mapping relationships among changing variables. An example would be: If I'm driving very fast and the car ahead of me is getting close, then a large force needs to be applied to the brakes. An imaginary car equipped with a fuzzy logic braking system would automatically apply the driver's foot pressure. The only brakes that are being controlled by fuzzy logic now are in Japanese subway cars designed by Hitachi, but Nissan and Isuzu have introduced fuzzy car transmissions to smooth out automatic gear shifting.

Fuzzy logic control is the newest wrinkle in the ancient science of controlling processes that involve constantly changing variables. The technology dates back to the Romans, who developed floating valves to maintain adequate water levels in their aqueducts. The thermostat on your wall is the same sort of control—it automatically regulates the temperature by switching on the air conditioner when the room temperature rises above a comfortable level.

Contrary to its name, fuzzy logic is a very precise subdiscipline in mathematics. It was invented in the 1960s by Berkeley's Russian-born Iranian computer science professor Lotfi Zadeh. It enables mathematicians and engineers to simulate human thinking by quantifying concepts such as hot, cold, very far, pretty close, quite true, most usually, almost impossible, very unlikely, middle-aged. It does this by recognizing that measurements are much more useful when they are characterized in linguistic terms than when taken to the fourth decimal point. Fuzzy logic reduces an infinite



Panasonic's video camera stores in its memory 120 points of reference (left). When the cameraman's hand shakes, a fuzzy logic controller notes that all the points have moved in the same direction and infers that what is moving is the camera and not the subject (center). Using the original points of reference, the image is then shifted to compensate for jitter (right).

spectrum of numbers into a few categories called membership groups.

Take, for example, the membership groups for a person's age—young, middle-aged and old. Few would argue with the propositions that a 20-year-old is young and an 80-year-old is old. But what is a 35-year-old? Fuzzy logic gives this person some degree of membership in the young group and a somewhat higher degree of membership in the middle-aged group. Not precise perhaps, but useful enough for most purposes.

For years U.S. companies scorned fuzzy logic, but in recent months many firms, among them Eaton, General Electric, General Motors, Hewlett-Packard, Honeywell and Rockwell, have begun to talk about commercial products using fuzzy logic that will soon hit the market. In the next few years fuzzy logic will be used in flying military aircraft, to operate automatic transmissions and cruise control in cars, inspect beverage cans, and help computers recognize handwriting.

Use of fuzzy logic can save time and money. Take the problem facing some Rockwell engineers designing controls for the Air Force/NASA advanced technology wing. They wanted to find out how fast they could send the wing into a roll before it reached a stress threshold. To do that, the engineers spent months writing formulas to approximate the stress on the wing caused by each of many different, constantly changing variables—air speed, shape of the wing in flight, drag, aerodynamics.

The Rockwell researchers used conventional techniques to control the wing in a wind tunnel. Then they tried to solve the same problem using fuzzy logic. Result: simpler rules, less math, more accurate representation of a complicated process. "The fuzzy logic control allowed us to roll three times faster and still keep the stress below the threshold," says Allen Firstenberg, director of information sciences at the Rockwell International Science Center in Thousand Oaks, Calif. "That is an example where it is so difficult to model the thing that fuzzy logic did a lot better than a mathematical model."

For a lot of systems, this kind of reasoning works nicely. Maybe not for cutting precision parts on a machine tool, but for plenty of other uses. Theoretically you could park a car to within hundredths of an inch of the curb, but what's the point? Fuzzy logic controls might leave an extra inch or two but would ease the car in without jumping the curb or scraping adjacent vehicles. "Humans rarely use numbers to solve problems," says Zadeh. "It's expensive to be totally precise. Fuzzy logic exploits the tolerance for imprecision."

By using fewer rules and simpler programming, fuzzy logic also has the virtue of speeding up the time it takes to get a new product to market and lowering the cost. Kyoto-based Omron is Japan's leading maker of factory controllers. Omron developed a fuzzy system for Komatsu to check machine tools for worn-out gears or dirty oil filters. Omron says using fuzzy logic slashed development time by 75%. Omron has applied for 700 patents on fuzzy logic in Japan and projects sales of $750 million, or nearly 20% of total revenues, from products incorporating fuzzy logic by 1994.

American companies are finding plenty of opportunities for fuzzy products. Rockwell's Allen-Bradley unit is working on some fuzzy controllers for factory automation. Eaton Corp. has a fuzzy color sensor that is being used to inspect beverage cans for printing defects—a major source of waste. Food processors, printers and packaging firms need to inspect their products for color, but the job now is performed by humans or by $50,000 instruments that periodically inspect samples in a lab. Eaton's sensor, at around $5,000, can be trained to recognize a range of acceptable shades of a color—say, Coca-Cola red—at assembly line speeds.

Meanwhile, the Japanese have been marketing their fuzzy consumer products like crazy. Matsushita, the world's largest consumer electronics firm, touched off the boom last year when it began shipping its fuzzy logic washing machine. After placing laundry in the washing machine, the user simply pushes the start button. The machine does the rest. Two simple optical sensors analyze the dirt in the wash and the size of the load. The information is fed to an inexpensive fuzzy microprocessor that selects wash, rinse and spin cycle times from among 600 possible combinations. Fuzzy logic models already account for over half of Matsushita's washing machine sales in Japan.

The success of the Japanese fuzzy products has finally alerted American business people, who had until recently ignored the technology. Says Masaki Togai, a founder of fuzzy chip maker Togai InfraLogic Inc. of Irvine, Calif.: "We cannot believe the interest today." A year ago over 90% of the firm's sales of fuzzy chips and programming tools went to Japanese customers; Togai projects that by the end of this year revenues will be evenly split among American, European and Japanese clients.

Fuzzy logic pioneer Zadeh is still something of a heretic in U.S. academic circles, but he is regarded as a prophet and visionary in Japan. Mention of Zadeh's name is enough to bring a smile to the face of the most dour Japanese engineer. But the Berkeley computer scientist has no patents on fuzzy logic and receives no royalties. Says he: "I always buy used cars; my needs are very modest. I have no regrets whatsoever."

–ANDREW TANZER AND G.S. ■

Togai dedicated to fuzzy logic

By R. Colin Johnson

Irvine, Calif. — Togai InfraLogic Inc., the first U.S. company dedicated to fuzzy logic, is moving rapidly to become the first worldwide full-spectrum vendor of fuzzy engineering services, software, and hardware by using the experience it gains from its contract work to build standard products. Several standard parts are now ready to hit the market.

The first new product is its single-chip classifier sorter (CS) device. The CS chip was originally developed as an engineering solution to a *kanji* optical character recognition (OCR) project done under contract with Canon Inc. Now Togai InfraLogic has released the part for any classification task.

The second device is the spatial filter chip, to be announced later this year. Originally developed for a high-definition television application in Japan, the chip is capable of processing 50 million pixels per second for convolutions and similar filtering applications.

Togai InfraLogic was founded by Masaki Togai. While at AT&T Co. in 1986, Togai, along with fellow researcher Hiroyuki Watanabe, fabricated one of the first fuzzy microchips (Kyushu Institute of Technology professor Takeshi Yamakawa made the other, also in 1986). AT&T declined to pursue the technology, however, and Togai moved to Rockwell International Corp. Former Rockwell executive Frank Lundberg, unable to drum up adequate corporate support for fuzzy logic, advised Togai to start his own company. Lundberg is now president of Togai InfraLogic.

By the end of 1988, Togai InfraLogic had introduced its Fuzzy-C Development System—a precompiler that allows fuzzy logic to be easily embedded into any C-language application program. It followed in early 1989 with the FC110 digital fuzzy processor, an 8-bit fuzzy microprocessor. Later that year, the company introduced a single-board computer as well as a board for the AT bus using the FC110. A board for the VMEbus followed in 1990.

Also in 1990, the company showed the world's first computer-aided software engineering (CASE) tool, a graphical editor for fuzzy logic called the TILShell. Another first in 1990 was its software-development environment aimed at embedded microprocessors—MicroFPL. This fuzzy programming language is used to embed fuzzy logic into standard microcontrollers, such as Motorola Inc.'s 6811.

It might sound like Togai InfraLogic already is a full-spectrum vendor, but not according to Lundberg. "We have amassed a vast amount of engineering knowledge while working with individual clients that we also want to pass on to others," he said.

The company is eager to lend its expertise to anyone developing a fuzzy-logic-based product. "Our engineering tools are completely adequate, but they can't substitute for the hard-won engineering knowledge we can apply to specific problems," Lundberg said. The company is opening offices in Munich and Tokyo for consulting and support services, as well as for in-house seminars and prototype demonstrations for its customers.

Next for Togai InfraLogic is the introduction of the CS chip. "The CS device can handle many different classification applications," said vice president of operations Dan Bochsler. "Pattern recognition is just the most obvious."

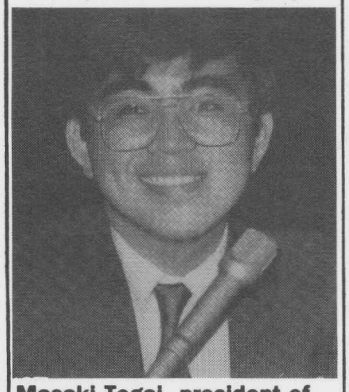
The features that define a pattern must first be fashioned into a vector for the CS. Once such a vector is input, the CS searches a dictionary of feature vectors to find matches. When finished, the CS device has calculated the closeness of the new sample to each dictionary entry, sorting that list into the 100 (or 52) closest (or furthest) matches.

The CS device brings each new feature vector into its on-chip RAM, before comparing it with each of the entries it keeps in an off-chip dictionary. Each vector can be up to 201 16-bit words long and dictionaries can have up to 8191 entries. The CS device's clock runs at 20 MHz. It uses 120,000 transistors, is cast in CMOS, and consumes 1.2 watts. The chip comes in 120-pin PGA.

Following will be the introduction of the Spatial Filter Chip, which processes a 3-pixel-by-3-pixel moving frame (8 bits per pixel) for convolutions and uses 27-bit-wide internal data paths to prevent overflow problems.

Other hardware under development for release in late 1991 or 1992 includes a FC110 board for the S-bus and an improved board for PCs, called the XT board, which uses I/O rather than memory mapping. An in-circuit-emulator for the FC110 is also planned, as is a 16-bit version of the FC110 itself.

On the software scene, Horstkotte said the MicroFPL development system was also going to support 16-bit microprocessors and may add the popular Intel 8051 to its list of compatible microcontrollers. Horstkotte also said the company plans to support the X-Windows interface for Sun and other Unix-based workstations.



Masaki Togai, president of Togai InfraLogic

In addition, Togai InfraLogic plans a lower-priced version of its basic development environment, called the Personal Fuzzy C Development System, and is working on a graphing module for its CASE tool. Work the company is doing for NASA on a fuzzy expert system, called Fuzzy CLIPS (C language integrated production system), will also be made available to others.

Perhaps the most ambitious encapsulation of fuzzy engineering knowhow, however, is going into its forthcoming neural-network front end for its fuzzy logic tools. "Neural networks will change the way everybody builds fuzzy logic systems," Togai asserted. In Japan, many companies are developing neural front-ends for fuzzy logic systems (see Aug. 20, 1990, page 1). But Togai InfraLogic is the first company in the United States to apply neural networks to learning fuzzy logic rules.

According to Togai, a problem that has lengthened the learning curve for companies first applying fuzzy logic is the ill-defined method of coming up with the rules for an application. "There is no numerical way to find a good rule," Togai said. "That is why we are using neural networks to learn them.

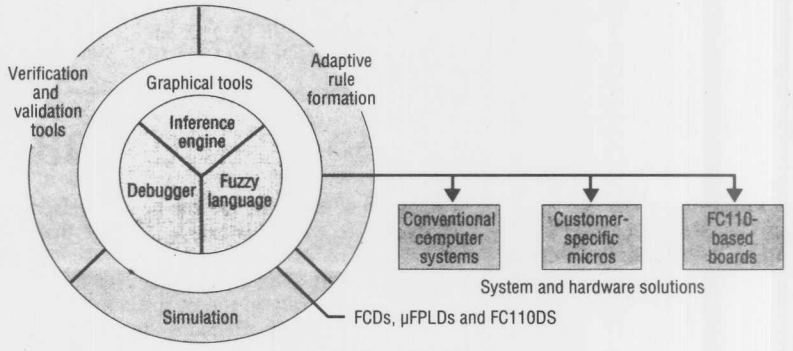
"We used to work by taking every possible rule and then trimming them down to a minimal set," he said. "But the neural network has reversed that strategy by providing the core set of most-often-used rules, so all we have to add is rules to cover the exceptional cases."

The specific neural method being explored at the company was created by Bart Kosko, a professor at the University of Southern California (Pasadena). Called differential competitive learning (DCL), it is based on the adaptive vector quantization method invented by Tuevo Kohonen at the Helsinki University of Technology.

It uses training data to learn a control surface which can be automatically decoded into a set of fuzzy rules. The process clusters together the vector product-space that approximates the underlying control surface. Fuzzy rules are then determined by partitioning that product space.

FUZZY LOGIC ON A CHIP

The evolution of Togai InfraLogic's product line



U.S. fuzzy logic comes out of the closet

By R. Colin Johnson

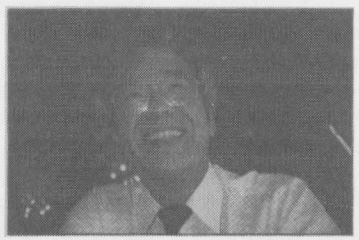
Austin, Texas — U.S. researchers looking into fuzzy-logic-based systems came out of the closet at the recent Industrial Conference on Fuzzy Systems, sponsored here by Microelectronics and Computer Technology Corp. Even the government, which many had thought to be dragging its feet in non-defense-related research, disclosed many current efforts.

MCC also revealed that it will spin out a company to apply neural networks and fuzzy logic (see related story, page 19).

As the popularity of fuzzy logic has grown in Asia, the United States has yet to mount significant commercial competition. For instance, "this year in Japan, the word 'fuzzy' was elected the best word of the year," said Takeshi Yamakawa, director of the Fuzzy Logic Systems Institute and professor at Kyushu Institute of Technology in Japan. But U.S. leaders have continued their prejudice against a technology that enshrines approximate reasoning.

"Many U.S. advisers make emotional arguments, calling imprecise reasoning bad reasoning, when they have as yet not even a basic understanding of the technology," lamented the inventor of fuzzy logic, Lofti Zadeh, professor at the University of California at Berkeley.

But as market size has grown, U.S. technologists have begun to develop fuzzy logic despite intellectual biases against it. The reasons are clear. For example, one of the most active companies in Japan, Omron Tateishi Electronics Co. (Kyoto), has estimated that it will gross $500 million per year from fuzzy systems by 1995.

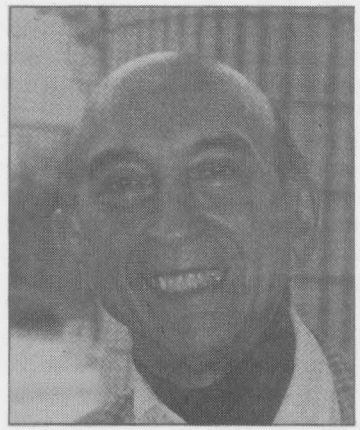


Takeshi Yamakawa: "This year in Japan, we elected 'fuzzy' as the best word of the year."

Likewise, Masaki Togai, founder of Togai InfraLogic (Irvine, Calif.), estimates a $5 billion total world market by 1995. "If the U.S. is to share in that market, it must quicken the pace of its fuzzy-logic development efforts," Togai said.

MCC was spawned in 1982 for just this reason, albeit only recently for fuzzy logic in particular. MCC is an industry consortium of U.S. companies that pool their resources in an effort to combat similar research-and-development efforts by foreign governments—principally Japan. Its many participating companies include Bell Communications Research Corp. Inc., Control Data Corp., Digital Equipment Corp., Eastman Kodak Co., Harris Corp., and NCR Corp. In the past, sponsors had to support the whole effort. But in 1989, MCC unbundled its sponsorship commitments and now allows companies to participate on a per-project basis.

The conference was called to announce to the world that MCC had added fuzzy logic as its fifth major research area (behind artificial intelligence, natural language, neural networks, and database technology). MCC advertised it as the meeting place for U.S. industry interested in pooling fuzzy-logic development resources. As a consequence, more formerly secret domestic fuzzy-logic projects were revealed there, so far, than anywhere else.



Lofti Zadeh: The U.S. is still resisting fuzzy logic on emotional grounds.

"We are inviting U.S. industry to share in our development of this exciting new technology," explained Steve O'Hara, conference organizer at MCC. "This conference, we hope, will attract attention to the fact that fuzzy-logic-based applications can be quickly developed while your engineers are learning about it," he said.

MCC's fuzzy-systems project initially will concentrate on three application areas to develop with its members: process control, image processing and enterprise modeling. Its plan calls for developing at least four small applications in 1992 for companies with specific needs (with a deadline of Jan. 1, 1992 for proposals). It then will mine the experience thus gained to generate a fuzzy-logic development environment by 1993.

The environment to be developed is named Craft—common run-time architecture for fuzzy technologies. Craft has several design goals:

- Independence from specific hardware and fuzzy-logic methods.
- Distributed architecture.
- Hierarchical organization.
- Hybrid construction, featuring neural networks and traditional technologies.

Heterogeneous systems support for Craft's components will

probably consist of an interpreter and a run-time kernel. It will eventually be delivered to participants who will then be encouraged to develop applications in conjunction with MCC.

Presentations at the conference uncovered a plethora of previously unrevealed research projects in the United States.

"Fuzzy logic, neural networks, genetic algorithms and other advanced techniques are going to be mandatory for the information technologies of the future," explained Maria Zemankova, the National Science Foundation's (NSF) program director. In a handout, Zemankova cited 48 separate research projects dedicated to applying emerging technologies to outstanding problems.

Speakers addressed over 300 attendees, mostly from industry.

Allen-Bradley (Milwaukee) was perhaps the most forthright about its development efforts, which are aimed at a line of fuzzy-logic-based industrial controllers to replace conventional proportional-integral-differential (PID) devices. "We recognize the strategic importance of fuzzy logic to our product lines and are reacting accordingly," said Peter Schmidt, an Allen-Bradley researcher. Schmidt described an industrial controller he developed that uses fuzzy logic for optimal PID loop gain tuning. He reported that Allen-Bradley will perhaps be the first U.S. company to offer fuzzy-logic controllers that have been created from a development environment the firm devised for building such systems.

United Technologies (Los Angeles) revealed that three of its major divisions (elevators, helicopters and jet engines) were working separately on fuzzy-logic-based systems. Researcher Mike Griffin described his work using fuzzy logic to test jet engines. A special wind tunnel currently uses a human operator to control most of its functions, forcing frequent, tedious adjustments to prevent damage to the structure or the engine.

Originally, Griffin developed a traditional controller to off-load some of that manual tuning. However, it took over two months, and a detailed model of the wind tunnel had to be created. Since fuzzy logic does not require such a model, a controller with equal performance was developed with fuzzy logic in just three days. "We haven't put any human operators out of a job yet, but the project has demonstrated to management how much productivity can be gained by using fuzzy logic," Griffin said.

In the defense sector, the Electronics and Space Corp. (St. Louis) allowed University of Missouri professor Jim Keller to reveal some aspects of the firm's continuing fuzzy-logic efforts. Since much of its work is defense-related, Electronics and Space is first applying fuzzy logic to automatic target recognition. The company also has incorporated neural techniques so that its systems can learn from experience.

In the private sector, Ford Motor Co. (Dearborn, Mich.) revealed that it had been doing fuzzy research and development, supported by the Georgia Institute of Technology, since 1989.

Beyond research

"We have gone through the major theoretical approaches and identified those areas where fuzzy logic will reduce our cost while improving performance," said Ford researcher Lee Feldkamp. He said that the auto maker was beyond the research stage now and is building hardware prototypes using a combination of fuzzy logic and neural networks.

Motorola Inc.'s microcontroller division (Austin) said that it stood ready to help the automotive industry incorporate fuzzy logic into its systems. Researcher Michael Catherwood said that Motorola is developing digital microcontroller technology that makes use of fuzzy logic, though he was vague about whether standard products would be offered. "By 2000, almost 14 percent of a car's cost will be tied up in electronics, compared with 8 percent today, making economical use of fuzzy logic very attractive," he noted.

A likely candidate for early deployment is Motorola's customer-specific integrated circuits. These high-density chips are built for customers who choose from a set of standard modules. A fuzzy-logic module will be added in the near future, Catherwood indicated.

FC110 Board Product Specifications

FC110 Development Module

- On-board 20 MHz FC110 Processor
- 128K of knowledge base EPROM
- Small form factor (4″ × 2.5″)
- 8 bits of extended address
- Configurable for all FC110 operating modes

AT Accelerator Board

- Compatible with IBM PC/AT bus standards
- On-board 20 MHz FC110 Processor
- 128K bytes of knowledge base RAM
- Supports 64 processors per host
- Interrupt facilities available
- Knowledge base is memory mapped to the bus
- FC110 shared memory is I/O mapped to the bus

Single-board Fuzzy Controller

- On-board 20 MHz FC110 Processor
- 128K bytes of knowledge base EPROM
- 8 Analog input channels (8-bits)
- 4 Analog output channels (8-bits)
- (5) 8-bit Programmable Timers
- Programmable Serial Asynchronous Communication Interface
- (2) 8-bit Programmable Parallel I/O Ports
- Eight-Level Priority Interrupt Controller
- Dimensions: 5″ × 4″

VME Accelerator Board

- (4) 20 MHz FC110 Processors per board
- 128K bytes of knowledge base RAM per processor
- Maps completely within 256K bytes of system address space
- Prioritized vectored interrupts from 8 sources (2 per processor)
- User defined address modifier
- IEEE P1014 (Rev. C) VME-bus compatible
- 6U form factor
- Supports all levels of interrupts
- Supports 256 processors per host

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TOGAI INFRALOGIC INC.

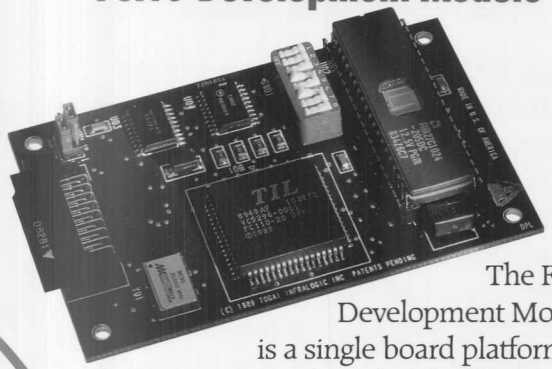
Board-Level Solutions

Togai InfraLogic (TIL) offers more ways to integrate fuzzy logic into your applications than anyone else. TIL's line of board-level products ranges from fuzzy logic accelerator boards to embedded control subsystems.

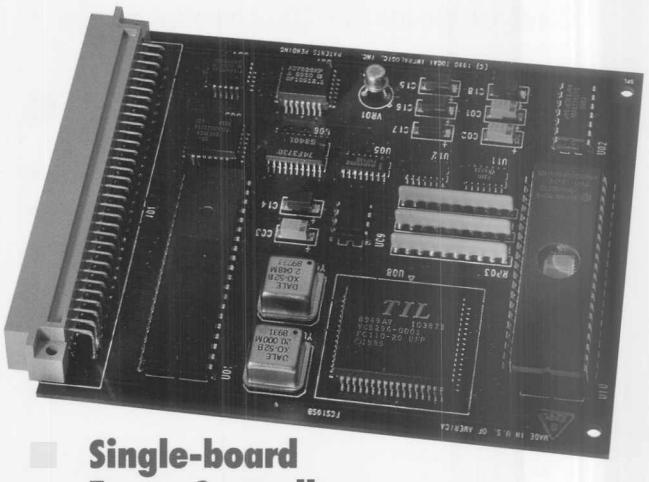
The FC110 Foundation

A unique device, the FC110 Digital Fuzzy Processor (DFP™), is at the heart of all Togai InfraLogic hardware solutions. Designed from the ground up for real-time, embedded fuzzy logic control applications, the CMOS FC110 can perform more than 200,000 fuzzy rule evaluations per second.

FC110 Development Module

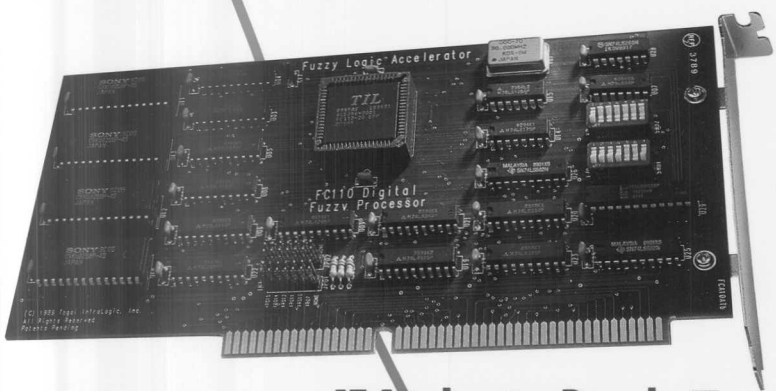


The FC110 Development Module is a single board platform for developing FC110-based embedded expert systems. The board is designed to be connected to a host system requiring acceleration of fuzzy logic inferencing.



Single-board Fuzzy Controller

TIL's Single-board Fuzzy Controller is a powerful stand alone unit designed for fuzzy logic control applications. In addition to the FC110, the 5″ × 4″ board provides the resources necessary to form a complete fuzzy control module.

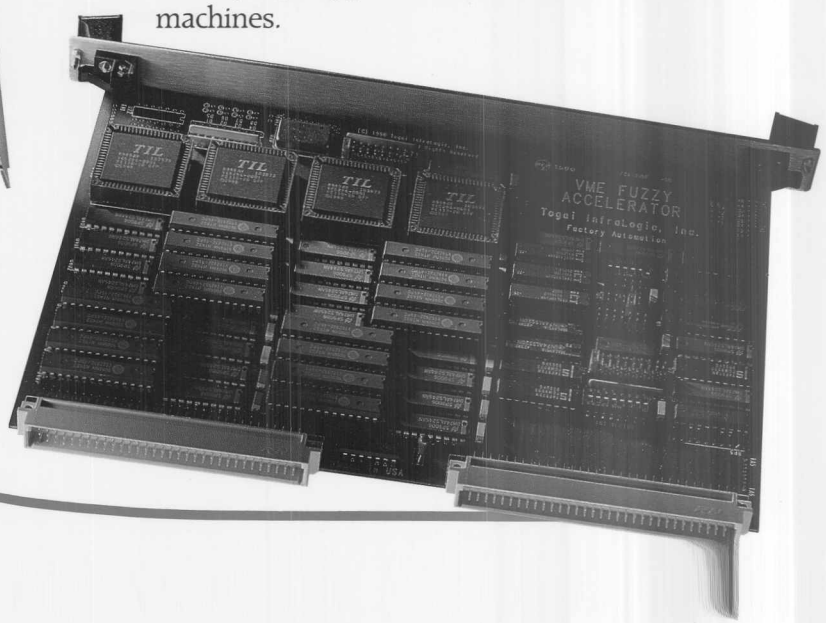


AT Accelerator Board

Designed for the IBM PC/AT® bus, the AT Accelerator Board allows the development and evaluation of complex fuzzy logic applications on a personal computer.

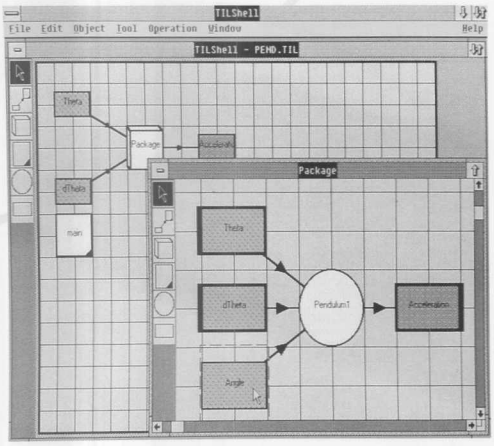
VME Accelerator Board

A high performance single board fuzzy logic accelerator, the VME Accelerator Board is designed for the development and evaluation of complex real-time fuzzy logic applications on VME-based machines.



TILShell: An Object-Based, Fuzzy Logic Development Environment

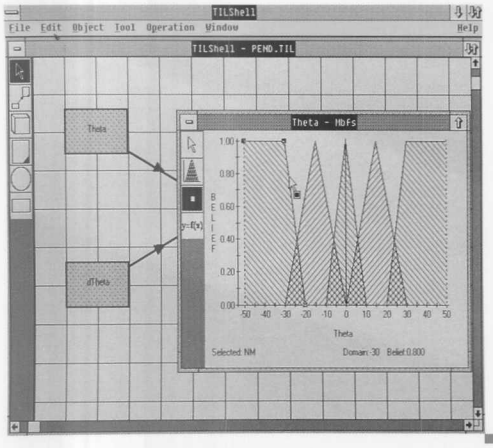
Togai InfraLogic offers more ways to integrate fuzzy logic into your applications than anyone else – including TILShell,™ a powerful, graphical, object-based, "point-and-click" CASE tool.



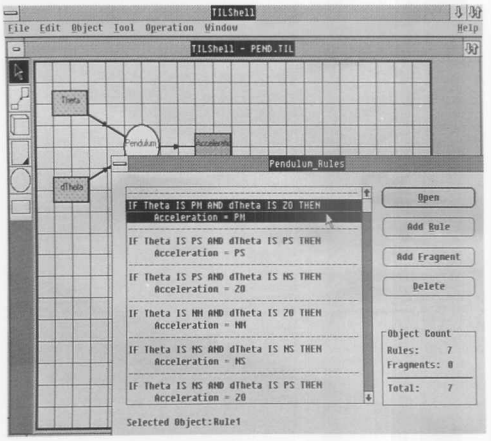
Making it Easy

With TILShell you can create stand alone fuzzy logic expert systems or effortlessly integrate the power of fuzzy logic into your existing applications. Key development capabilities include the ability to easily and quickly:

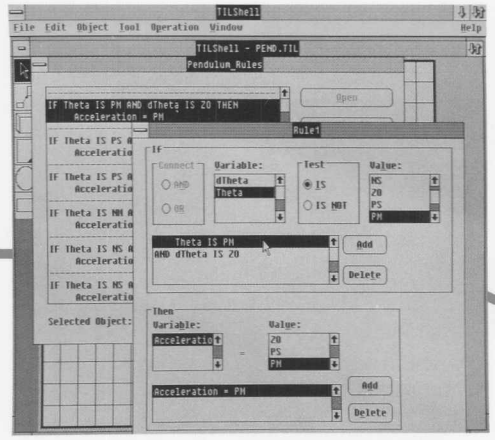
■ Design the inputs, outputs, and processing objects of your system and their interrelationships using the **Project Editor.**



■ Create simple (piecewise-linear) and complex (equation based) membership functions using the **Membership Function Editor.**



■ Construct a rulebase from a set of fuzzy logic rules using the **Fuzzy Editor.**



■ Add new rules, or add, modify and delete premises and conclusions to an existing rule, using the **Rule Editor.**

■ Use the **Compile** command to compile an overall system description, including fuzzy logic production rules and membership functions, to either portable C source code, machine code for Togai InfraLogic's FC110 VLSI Digital Fuzzy Processor, or optimized, microprocessor-specific assembly code.

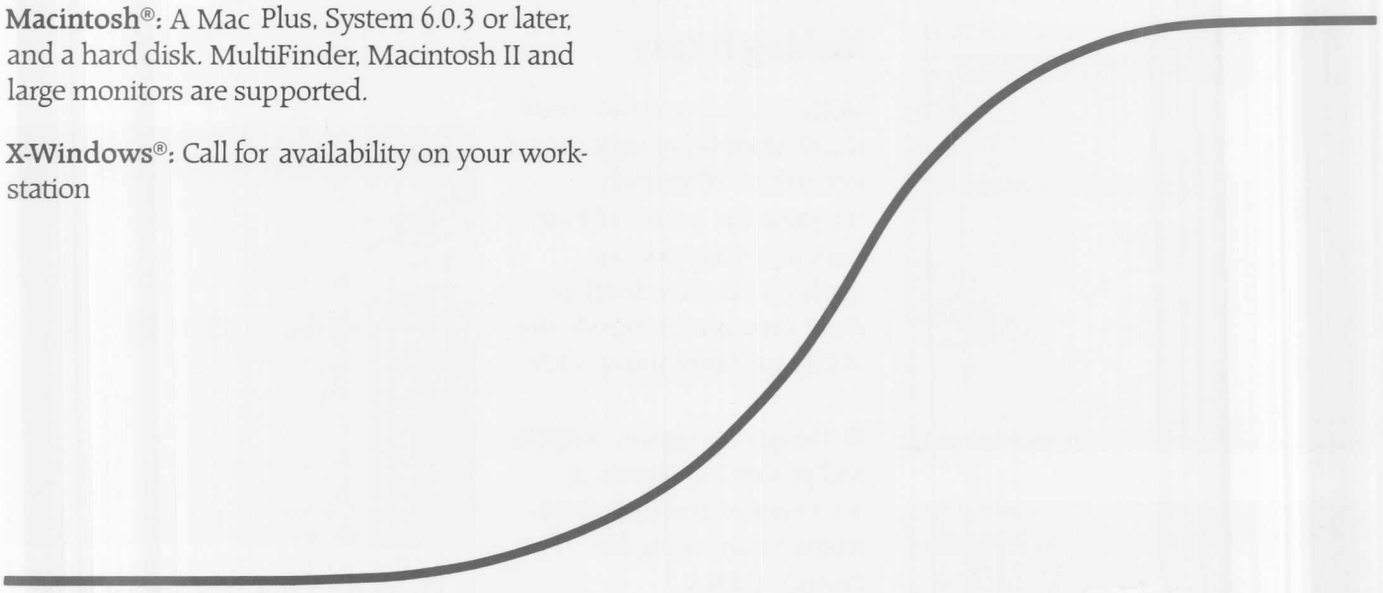
In addition to built-in ease of use, Togai InfraLogic's support hot-line and comprehensive documentation also make working with TILShell a breeze.

System Requirements

IBM PC® 286 or 386 Compatibles: MS Windows® (2.1 or higher), 2MB RAM, an EGA or VGA monitor, and a hard disk.

Macintosh®: A Mac Plus, System 6.0.3 or later, and a hard disk. MultiFinder, Macintosh II and large monitors are supported.

X-Windows®: Call for availability on your work-station



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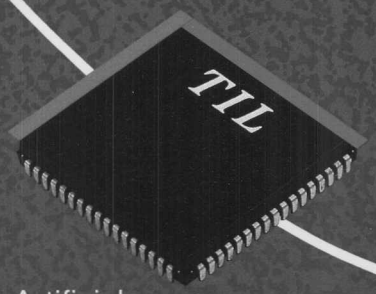
T O G A I I N F R A L O G I C : *The World's Source for Fuzzy Logic Solutions*

TOGAI INFRALOGIC INC.



Artificial
Intelligence
on a Chip

Togai InfraLogic: The World's Source for Fuzzy Logic Solutions

Fuzzy Logic Works

The fuzzy logic revolution is real. It's here. And Togai InfraLogic has been putting it to work for companies around the world since 1987.

Today's technology leaders know what fuzzy logic is. In fact, fuzzy logic has already been applied with great success to create:

- Expert systems for medical diagnoses, scheduling and control, sales, economics, marketing research and stock performance prediction, business management decision making and industrial design.
- Automotive systems for automatic transmission control, fuel injection, active suspension control and anti-skid braking.

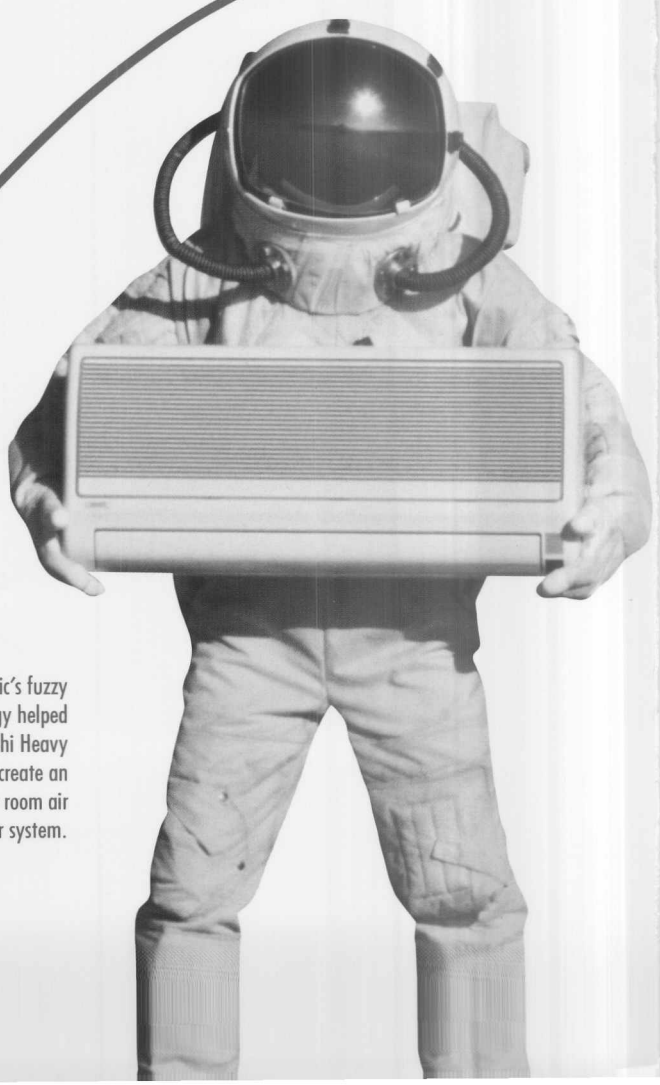
- Control systems for consumer electronics products ranging from still and video cameras to air conditioners and microwave ovens.
- Industrial systems for elevator, rail system, robot and motor control.
- Aerospace systems for flexible wing control, jet engine failure diagnostics, cockpit resource management and spacecraft positioning control.

In every application, fuzzy logic-based control systems outperform their traditional "yes/no" binary logic counterparts in terms of accuracy, flexibility and smooth responsiveness to rapidly changing conditions.

Togai InfraLogic Software and Hardware Solutions

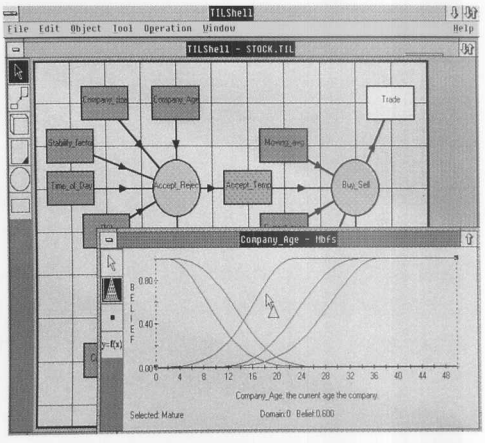
Togai InfraLogic (TIL) offers more ways to integrate fuzzy logic into your applications than anyone else. TIL's line of products ranges from a graphical, object-based, fuzzy logic software development environment to fuzzy logic accelerator boards and embedded control subsystems using the TIL designed VLSI Digital Fuzzy Processor (DFP™) chip.

A unique device, the FC110 Digital Fuzzy Processor, is at the heart of all Togai InfraLogic hardware solutions. Designed from the ground up for real-time, embedded fuzzy logic control applications, the CMOS FC110 microprocessor can perform more than 200,000 fuzzy rule evaluations per second. The FC110 also drives a wide range of Togai InfraLogic subsystem products including a PC/AT accelerator board, a single-board fuzzy controller, a VME-bus accelerator board and a stand alone development module.

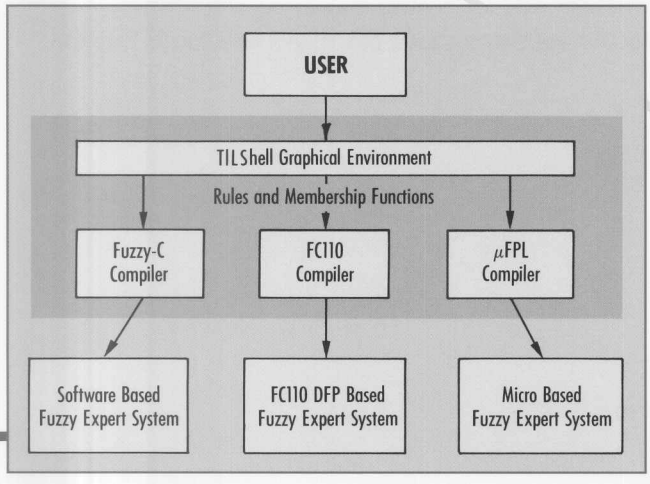


Togai InfraLogic's fuzzy logic technology helped Mitsubishi Heavy Industries create an intelligent room air conditioner system.

Shown here is the high level design of a fuzzy logic stock trading system developed with the TILShell™ graphical, object-based, fuzzy logic software development environment.



Software Tools



Togai InfraLogic provides tools to implement fuzzy logic systems from software to silicon. With the TILShell™ you can quickly define the overall structure of a system, including fuzzy logic production rules and membership functions. Using the company's Fuzzy-C,™ FC110, or MicroFPL™ Compilers you can compile a system description to either portable C source code, machine code for the FC110, or optimized microprocessor-specific code.

Togai InfraLogic software tools run on a host of popular platforms – 286-, 386-, and 486-based PCs, the Apple Macintosh®, and most popular workstations from Sun, HP-Apollo and others.

Consulting Services

Togai InfraLogic's solutions go beyond products to include consultative services. The Company's team of experts have helped many of the world's largest companies bring their fuzzy logic-based applications from concept to reality – on time and on budget. And with their proven capabilities to design, test and fine-tune highly complex expert and control systems, the professionals at Togai InfraLogic can serve as your powerful fuzzy logic or neural network resource.

The Company

Irvine, California-based Togai InfraLogic was founded in 1987 as the world's first company dedicated to the application of fuzzy logic. The Company's founders and members of the board are recognized as pioneers in the area of artificial intelligence and expert systems based on fuzzy logic and neural network theory.

When the editors of Business Week, Time and Newsweek set out to write about fuzzy logic they cited Togai InfraLogic as a leader in the field. In addition, the top USA technology press has often honored the Company, including a "1990 Product of the Year" award from Electronic Products magazine for the FC110 Digital Fuzzy Processor.

Building on a base of remarkable growth in demand for its products and services in the Asian market, the Company is actively expanding its activities throughout North America and Europe.

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Togai InfraLogic, Inc.

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RETAIL Price List

Effective August 1, 1991

SOFTWARE

Item	Description		Price
TILShell	Object based, graphical software development environment for fuzzy expert systems. Interfaces directly with the Fuzzy-C, MicroFPL, or FC110 Development Systems.		
	IBM-TES-02E	TILShell for IBM PC	$2,300
	MAC-TES-02E	TILShell for Macintosh (available only as TILShell/FCDS package)	
	SUN4-TES-02E	TILShell for Sun-4	$3,300
	NEC-TES-02E	TILShell for NEC PC	$2,300
TILGen	An automated rulebase generation tool. Using the definitions of the inputs and outputs of a system and an input data file, TILGen will generate a fuzzy rulebase. Uses the latest in neural network techniques to analyze your inputs and generate its output rulebase.		
	IBM-TG-01E	TILGen for IBM PC (Windows or MS-DOS version)	$975
	MAC-TG-01E	TILGen for Macintosh	$975
	SUN4-TG-01E	TILGen for Sun-4	$1,395
	NEC-TG-01E	TILGen for NEC PC	$975
Fuzzy-C Development System	Fuzzy-C compiler which generates C source code with in-line fuzzy inference engine knowledge base and membership functions. Includes debugging library with source and TILChart, a graphical analysis tool.		
	IBM-FCS-02E	Fuzzy-C Development System for IBM PC	$2,490
	MAC-FCS-02E	Fuzzy-C Development System for Macintosh (see TILShell for Mac)	
	SUN3-FCS-02E	Fuzzy-C Development System for Sun-3	$3,900
	SUN4-FCS-02E	Fuzzy-C Development System for Sun-4	$3,900
	APL-FCS-02E	Fuzzy-C Development System for HP/Apollo 9000/400	$3,900
	NEC-FCS-02E	Fuzzy-C Development System for NEC PC	$2,490
	SNY-FCS-02E	Fuzzy-C Development System for Sony News	$3,900
MicroFPL Development System	A micro fuzzy processing kernel and compiler which generates compact fuzzy expert systems, with linkable runtime fuzzy interpreter kernel for the specific target microprocessor. This price includes usage of 10 runtime kernels. Call for production licensing for the runtime kernel component.		
	IBM-377FPL-01E	MicroFPLDS for Mitsubishi 37450 (host:IBM PC)	$2,000
	NEC-377FPL-01E	MicroFPLDS for Mitsubishi 37450 (host:NEC PC)	$2,000
	IBM-H83FPL-01E	MicroFPLDS for Hitachi H8/300 (host:IBM PC)	$2,000
	NEC-H83FPL-01E	MicroFPLDS for Hitachi H8/300 (host:NEC PC)	$2,000
		MicroFPLDS for any other target microprocessor	Quote
FC110 Development System	Converts fuzzy logic knowledge base to FC110 based products. This product also includes an assembler and linker for the FC110 processor.		
	IBM-FC110-01E	FC110 Development System for IBM PC	$750
	NEC-FC110C-01E	FC110 Development System for NEC PC	$750

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RETAIL Price List

Effective August 1, 1991

SOFTWARE

Item	Description	Price
TILShell Eval	The TILShell graphical expert system shell without file save or compile capability. Although this package does not include the Fuzzy-C Development System, it does include the manual for the Fuzzy-C Development System. The purchase price for the TILShell Evaluation Package can be applied toward the purchase of the TILShell or a TILShell package.	
	IBM-TES-01DE — TILShell Evaluation Package for IBM PC	$300
	MAC-TES-01DE — TILShell Evaluation Package for Macintosh	$300
	SUN4-TES-01DE — TILShell Evaluation Package for Sun-4	$450
	NEC-TES-01DE — TILShell Evaluation Package for NEC PC	$300
Personal Fuzzy-C Development System	Exploratory and training version of the Fuzzy-C Development System. Supports the floating point data type, twelve rules and three variables.	
	IBM-PFCS-02E — Personal Fuzzy-C Development System for IBM PC	$350
	MAC-PFCS-02E — Personal Fuzzy-C Development System for Macintosh	$350
	SUN3-PFCS-02E — Personal Fuzzy-C Development System for Sun-3	$500
	SUN4-PFCS-02E — Personal Fuzzy-C Development System for Sun-4	$500
	APL-PFCS-02E — Personal Fuzzy-C Development System for HP/Apollo	$500
	NEC-PFCS-02E — Personal Fuzzy-C Development System for NEC PC	$350
	SNY-PFCS-02E — Personal Fuzzy-C Development System for Sony News	$500

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RETAIL Price List

Effective August 1, 1991

MAINTENANCE & SERVICES

Item	Description	Price
TILShell	IBM-TES-02 (per year)	$230
	MAC-TES-02 (per year)	$230
	SUN4-TES-02 (per year)	$330
	NEC-TES-02 (per year)	$230
TILGen	IBM-TG-01 (per year)	$100
	MAC-TG-01 (per year)	$100
	SUN4-TG-01 (per year)	$140
	NEC-TG-01 (per year)	$100
TILShell / FCDS / Package	IBM-TES-01 (per year)	$460
	MAC-TES-01 (per year)	$460
	SUN4-TES-01 (per year)	$690
	NEC-TES-01 (per year)	$460
TILShell / FCDS / TILGen Package	IBM-TFG-01 (per year)	$550
	MAC-TFG-01 (per year)	$550
	SUN4-TFG-01 (per year)	$780
	NEC-TFG-01 (per year)	$550
FCDS / TILGen Package	IBM-FCG-01 (per year)	$340
	MAC-FCG-01 (per year)	$340
	SUN4-FCG-01 (per year)	$480
	NEC-FCG-01 (per year)	$340
Fuzzy-C Development System	IBM-FCS-02 (per year)	$250
	MAC-FCS-02 (per year)	$250
	SUN3-FCS-02 (per year)	$390
	SUN4-FCS-02 (per year)	$390
	APL-FCS-02 (per year)	$390
	NEC-FCS-02 (per year)	$250
	SNY-FCS-02 (per year)	$390
Personal Fuzzy-C Development System	IBM-PFCS-02 (per year)	$50
	MAC-PFCS-02 (per year)	$50
	SUN3-PFCS-02 (per year)	$75
	SUN4-PFCS-02 (per year)	$75
	APL-PFCS-02 (per year)	$75
	NEC-PFCS-02 (per year)	$50
	SNY-PFCS-02 (per year)	$75
MicroFPL Development System	IBM-377FPL-01 (per year)	$300
	IBM-H83FPL-01 (per year)	$300
	NEC-377FPL-01 (per year)	$300
	NEC-H83FPL-01 (per year)	$300
FC110 Development System	IBM-FC110C-01 (per year)	$75
	NEC-FC110C-01 (per year)	$75
Chip/Board Design	Inhouse hardware design services available for chip and board design.	
Technical Services	Application engineering and support services, including seminars and consulting.	

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RETAIL Price List

Effective August 1, 1991

ADDITIONAL DOCUMENTATION

Item	Description	Price
TILShell	MN-TES-02E	$100
TILShell Eval	MN-TES-01DE	$200
TILGen	MN-TG-01	$50
Fuzzy-C Development System	MN-FCS-02E	$100
Personal Fuzzy-C Development System	MN-PFCS-02E	$100
FC110 Development System	MN-FC110C-01E	$100
MicroFPL Development System	MN-MFPL-01E	$100
AT Board	MN-FCA10AT-01	$25
SBFC Board	MN-FCS10SB-01	$25
SA Board	MN-FCD10SA-01	$25
VME Board	MN-FCA10VME-01	$25
FC110 Device	MN-FC110-01	$25
C/S Device	MN-CS-01	$25

All prices FOB Irvine, California, USA. All prices are in U.S. dollars and are subject to change without notice. Pricing does not include shipping or applicable tax. All software and hardware is under warranty for 90 days. Educational and quantity discounts are available. TILShell, TILChart, TILGen, Fuzzy-C, FPL, FC110, FCDS, PFCDS, MicroFPLDS, are registered trademarks of Togai InfraLogic, Inc. Macintosh is a registered trademark of Apple Computer, Inc. IBM-PC is a registered trademark of International Business Machines, Inc. Microsoft Windows, MS-DOS are registered trademarks of Microsoft Corporation. Sun is a registered trademark of Sun Microsystems, Inc. All other trademarks are acknowledged.

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RETAIL Price List

Effective August 1, 1991

HARDWARE

Item	Description		Price
AT Board	The FC110 based AT Accelerator Board is designed for high speed fuzzy rule processing on IBM PC/AT and compatibles. FC110 Development System for programming sold separately.		
	BD-FCA10AT-01	AT Accelerator Board	$950
SBFC Board	The Single Board Fuzzy Controller is an FC110 based embedded control node with analog and digital I/O. FC110 Development System for programming sold separately.		
	BD-FCS10SB-01	Single Board Fuzzy Controller	$1,500
SA Board	The Stand Alone Development Module is an FC110 based board designed for low cost embedded applications. FC110 Development System for programming sold separately.		
	BD-FCD10SA-01	Stand Alone Board	$400
VME Board	The VME Accelerator Board with up to four FC110 processors, is designed for high speed fuzzy logic rule processing. FC110 Development System for programming sold separately.		
	BD-FCA10VME-01	VME Accelerator Board with four FC110 processors	$4,500
	BD-FCA10VME-02	VME Accelerator Board with one FC110 processor	$4,000
	UP-FCA10VME-01	Single FC110 processor upgrade package	$300
FC110 Device	FC110 Digital Fuzzy Processor Device. All orders include an FC110 Electrical Specification and an FC110 Instruction Set manual. Prices per FC110 Device are based upon the total quantity ordered. FC110 Development System for programming sold separately.		
	DE-FC110-01	1 FC110 Device	$200
	DE-FC110-01	2-10 FC110 Devices	$150
	DE-FC110-01	11-99 FC110 Devices	$125
	DE-FC110-01	100-999 FC110 Devices	$100
	DE-FC110-01	1000+ FC110 Devices	$35
C/S Device	The Classifier/Sorter Device is designed to accelerate the tasks required for high speed pattern recognition systems and other classification operations. All orders include a C/S Device Electrical Specification. Prices per C/S Device are based upon the total quantity ordered.		
	DE-CS-01	1 C/S Device	$250
	DE-CS-01	2-99 C/S Devices	$180
	DE-CS-01	100-999 C/S Devices	$120
	DE-CS-01	1000+ C/S Devices	Quote

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RETAIL Price List

Effective August 1, 1991

SOFTWARE & HARDWARE PACKAGES

Item	Description		Price
TILShell / FCDS Package	Object based graphical expert system shell which includes the Fuzzy-C Development System.		
	IBM-TES-01E	TILShell and FCDS for IBM PC	$4,600
	MAC-TES-01E	TILShell and FCDS for Macintosh	$4,600
	SUN4-TES-01E	TILShell and FCDS for Sun-4	$6,900
	NEC-TES-01E	TILShell and FCDS for NEC PC	$4,600
TILShell / FCDS / TILGen Package	Object based graphical expert system shell which includes the Fuzzy-C Development System and TILGen.		
	IBM-TFG-01E	TILShell, FCDS, TILGen for IBM PC	$5,000
	MAC-TFG-01E	TILShell, FCDS, TILGen for Macintosh	$5,000
	SUN4-TFG-01E	TILShell, FCDS, TILGen for Sun-4	$7,400
	NEC-TFG-01E	TILShell, FCDS, TILGen for NEC PC	$5,000
FCDS / TILGen Package	The Fuzzy-C Development System and TILGen.		
	IBM-FCG-01E	FCDS and TILGen for IBM PC	$2,900
	SUN4-FCG-01E	FCDS and TILGen for Sun-4	$4,400
	NEC-FCG-01E	FCDS and TILGen for NEC PC	$2,900
SA Evaluation Kit	The Stand Alone Development Module Evaluation Kit includes one Stand Alone Board plus the FC110 Development System for one low price.		
	KT-FC110SA-01	Stand Alone Evaluation Kit	$995
AT Development Package	The AT Development Package includes one AT Board plus the FC110 Development System and TILShell in one complete set.		
	KT-FCA10AT-01	AT Development Package	$3,700

Togai InfraLogic, Inc.

Price List

Effective February 15, 1991

SOFTWARE

Item	Description	Price
TILShell	Object based, graphical software development environment for fuzzy expert systems. Interfaces directly with the Fuzzy-C, microFPL, or FC110 development systems.	
	IBM-TES-02E TILShell for IBM PC	$2,300
	SUN4-TES-02E TILShell for SUN4 (available Q2 '91)	$3,300
	MAC-TES-02E TILShell for Macintosh	$2,300
TILShell Demo	The TILShell graphical expert system shell without file save or compile capability. Although this package does not include the Fuzzy-C Development System, it does include the manuals for the Fuzzy-C Development System. The purchase price for the TILShell Demonstration Package can be applied toward the purchase of the TILShell or a TILShell package.	
	IBM-TES-01DE TILShell Demonstration Package for IBM PC	$300
	MAC-TES-01DE TILShell Demonstration Package for Macintosh	$300
	SUN4-TES-01DE TILShell Demonstration Package for SUN4 (Q2 '91)	$450
Fuzzy-C Development System	Fuzzy-C Compiler which generates C source code with in-line fuzzy inference engine, knowledge base and membership functions. Also includes debugging library with source.	
	IBM-FCS-02E Fuzzy-C Development System for IBM PC	$2,490
	SUN3-FCS-02E Fuzzy-C Development System for SUN3	$3,900
	SUN4-FCS-02E Fuzzy-C Development System for SUN4	$3,900
	APL-FCS-02E Fuzzy-C Development System for Apollo 3500, 4500	$3,900
	SNY-FCS-02E Fuzzy-C Development System for Sony News	$3,900
	MAC-FCS-02E Fuzzy-C Development System for Macintosh	$2,490
Personal Fuzzy-C Development System	Exploratory and training version of the Fuzzy-C Development System. Supports the floating point data type, twelve rules and three variables.	
	IBM-PFCS-02E Personal Fuzzy-C Development System for IBM PC	$350
	SUN3-PFCS-02E Personal Fuzzy-C Development System for SUN3	$500
	SUN4-PFCS-02E Personal Fuzzy-C Development System for SUN4	$500
	APL-PFCS-02E Personal Fuzzy-C Development System for Apollo 3500, 4500	$500
	SNY-PFCS-02E Personal Fuzzy-C Development System for Sony News	$500
	MAC-PFCS-02E Personal Fuzzy-C Development System for Macintosh	$350
MicroFPL Development System	Compiler which generates compact fuzzy expert systems, with linkable runtime fuzzy interpreter kernel for the specific target microprocessor. This price includes usage of 10 runtime kernels. Call for large, production volume pricing for the runtime kernel component.	
	IBM-377FPL-01E µFPLDS for Mitsubishi 37450 (hosted on the IBM PC)	$2,000
	IBM-H83FPL-01E µFPLDS for Hitachi H8/300 family (hosted on the IBM PC)	$2,000
	µFPLDS for any other target microprocessor	Quote
FC110 Development System	Converts fuzzy logic knowledge base to FC110 based products. This product also includes an assembler and linker for the FC110 processor.	
	IBM-FC110C-01E FC110 Development System for IBM PC	$750

HARDWARE

Item	Description	Price
AT Board	The FC110 based AT accelerator board is designed for high speed fuzzy logic rule processing on IBM PC/AT and compatibles. Requires an FC110 Development System for programming.	
	BD-FCA10AT-01 AT accelerator board	$950
SBFC Board	The Single Board Fuzzy Controller is an FC110 based embedded control node with analog and digital I/O. Requires an FC110 Development System for programming.	
	BD-FCS10SB-01 Single Board Fuzzy Controller	$1,500
SA Board	The Stand Alone Development Module is an FC110 based board designed for low cost embedded applications. Requires an FC110 Development System for programming.	
	BD-FCD10SA-01 Stand Alone board	$400
VME Board	The VME accelerator board with up to four FC110 processors, is designed for high speed fuzzy logic rule processing. Requires an FC110 Development System for programming.	
	BD-FCA10VME-01 VME accelerator board with four FC110 processors	$4,500
	BD-FCA10VME-02 VME accelerator board with one FC110 processor	$4,000
	UP-FCA10VME-01 Single FC110 processor upgrade package for VME board	$300
FC110 Device	FC110 digital fuzzy processor device. All orders include a FC110 Electrical Specification and an FC110 Instruction Set manual. Prices per FC110 device are based upon the total quantity ordered. Requires an FC110 Development System for programming.	
	DE-FC110-01 1 FC110 device	$200
	DE-FC110-01 2-10 FC110 devices	$150/ea.
	DE-FC110-01 11-99 FC110 devices	$125/ea.
	DE-FC110-01 100-999 FC110 devices	$100/ea.
	DE-FC110-01 1000+ FC110 devices	$35/ea.

SOFTWARE & HARDWARE PACKAGES

Item	Description		Price
TILShell / FCDS Package	Object based graphical expert system shell which includes the Fuzzy-C Development System.		
	IBM-TES-01E	TILShell and FCDS for IBM PC	$4,600
	SUN4-TES-01E	TILShell and FCDS for SUN4	$6,900
	MAC-TES-01E	TILShell and FCDS for Macintosh	$4,600
SA Evaluation Kit	The Stand Alone Development Module Evaluation Kit includes one Stand Alone board plus the FC110 Development System for one low price.		
	KT-FC110SA-01	Stand Alone Evaluation Kit	$995
AT Development Package	The AT Development Package includes one AT board plus the FC110 Development System and TILShell in one complete set.		
	KT-FCA10AT-01	AT Development Package	$3,700

Togai InfraLogic, Inc.

Price List

Effective
February 15,
1991

MAINTENANCE & SERVICES

Item		Price
TILShell	IBM-TES-02 (per year)	$230
	SUN4-TES-02 (per year)	$330
	MAC-TES-02 (per year)	$230
TILShell / FCDS Package	IBM-TES-01 (per year)	$460
	MAC-TES-01 (per year)	$460
	SUN4-FCS-01 (per year)	$690
Fuzzy-C Development System	IBM-FCS-02 (per year)	$249
	SUN3-FCS-02 (per year)	$390
	SUN4-FCS-02 (per year)	$390
	APL-FCS-02 (per year)	$390
	SNY-FCS-02 (per year)	$390
	MAC-FCS-02 (per year)	$249
Personal Fuzzy-C Development System	IBM-PFCS-02 (per year)	$50
	SUN3-PFCS-02 (per year)	$75
	SUN4-PFCS-02 (per year)	$75
	APL-PFCS-02 (per year)	$75
	SNY-PFCS-02 (per year)	$75
	MAC-PFCS-02 (per year)	$50
MicroFPL Development System	IBM-377FPL-01 (per year)	$300
	IBM-H83FPL-01 (per year)	$300
FC110 Development System	IBM-FC110C-01 (per year)	$75

Technical Services Application engineering and support services, including seminars, consulting and specialized application development support are also available. Call for information.

All prices FOB Irvine, California, USA.
Pricing does not include shipping or applicable tax.
All software and hardware is under warranty for 90 days.
Site licenses and educational discounts are available.

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